1. Purpose of Experiments
Include immediate goal of the experiments, scientific importance and/or programatic relevance.
Refer to any relevant program milestones.

Develop a relatively low density, steady H-mode target plasma for future LHCD experiments, while raising the temperature through high power RF heating. This will be used for LHCD scenario modelling and as a target plasma for 2003 experiments. We will also learn more about the scaling, and hopefully the physics, of the apparent ‘low density limit’ for EDA H-modes.

2. Background
Discuss Physics basis of the proposed research, Prior results at Alcator or elsewhere, and any related work being carried out separately.

It is well known that LHCD accessibility and efficiency are strongly dependent on electron density, with higher I_{CD} at lower density. Off-axis current localization also requires fairly high temperature, which will require simultaneous use of high power ICRH. For good confinement, then, the H-mode regime is preferable to L-mode. H-mode conditions should be steady to provide a good target for optimizing LH phasing and coupling. The EDA H-mode regime is the most attractive from this point of view; ELM-free H-modes are intrinsically transient and tend to ramp up density and impurities.

It has already been established from other MPs (eg. 278), that there is a lower limit in L-mode target density for achieving steady EDA with constant n_e[1]. At 800 kA, where most of the studies were done, the lowest achievable pedestal density was 2 \times 10^{20} m^{-3} (target nel = 9.6 \times 10^{20} m^{-2}); while the QC mode was seen at lower densities, its amplitude was apparently too low to arrest the density rise. This density is marginal for LH; while waves are accessible, the efficiency is low. Also, these plasmas had low heating power, and cool temperatures. Bonoli has carried out ACCOME modelling based on 1000914017 (see Fig.1); Driven current is only 80 kA, even with artificially increased T_e(0), and not well localized. Obviously, we need to improve on this. While we hope in future to control the
density using a cryopump, it is not clear whether this will alter the limitations set by EDA physics. It therefore seems worthwhile to study the apparent limit in more detail, and to see if lower density, high T, steady H-modes can be achieved.

$$J = J_{\text{oh}} + J_{\text{tot}} = J_{\text{bs}} + J_{\text{lh}}$$

$$I_p = 0.78 \text{ MA} \quad P_{lh} = 3 \text{ MW} \quad I_{lh} = 0.08 \text{ MA}$$

![Graph](image)

Fig. 1: Currents from ACCOME calculation based on H-Mode discharge 1000914017.

Hughes has established that, apart from the target density, the main variable affecting the ‘natural’ pedestal density is the plasma current, with

$$n_{\text{ped}} \propto I_p^{0.94} n_e^{0.4} L_B^{-0.46}$$

[2]. Higher q is also known to favour EDA. It is therefore plausible that lower density EDA H-modes can be achieved at lower current; this has not been explored systematically. We propose to do so here.

3. Approach

Describe the methodology to be employed; explain the rationale for the choice of parameters, etc. Describe the analysis techniques to be employed in interpreting the data, if applicable. If the approach is standard or otherwise self-evident, this section may be absorbed into the Experimental Plan.

The first part of the experiment, studying the low density threshold for EDA, can be done with moderate RF power (~2 MW, 80 MHz). We would start with 800 kA discharges, and lower the target density to re-establish the low density limit. The current would then be lowered to 700 kA and 600 kA, and the density scan repeated. Good pedestal data...
will be acquired so that we can define physical parameters (eq, collisionality, grad-P) that might affect the EDA/ELM-free boundary. Limited power scans at different densities will be used to help separate these variables.

The second part, which could if necessary be done on another day, would be to take one or two of the most promising, low density H-mode targets, and increase RF input power so as to maximize core $T_e(R)$. All 80 MHz would be best, though it seems that 70 MHz is also effective at raising $T_e$ if plasma is already in H-mode.

4. Resources

4.1 Machine and Plasma Parameters

Give values or range for:

- **Toroidal Field**: 5.4 T
- **Plasma Current**: 500-800 kA
- **Working gas species**: D
- **Density**: $n_e 0.5 – 1.0 \times 10^{20} m^{-2}$
- **Equilibrium configuration** (if possible, refer to database equilibria): Lower single null, moderate triangularity (take ‘best’ EDA shape from Martin’s runs)
- **Pulse length, typical current & density waveforms, etc.** Refer to database or sketch desired waveforms: Constant current, target density.

4.2 Auxiliary Systems

- **RF Power, pulse length, phasing**: 2-4 MW, 0.5 secs, all 80 MHz preferred.
- **Pellet Injection (species)**: no
- **Impurity blow-off injection**: no
- **Diagnostic Neutral Beam**: not essential
- **Special gas puffing**:

4.3 Diagnostics

List required diagnostics, and any special setup or configuration, e.g. non-standard digitization rate.

Edge and core TS, visible bremsstrahlung, ECE, PCI.
5. Experimental Plan

Both sections must be filled in.

5.1 Run sequence plan

Specify total number of runs required, and any special requirements, such as consecutive
days, no Monday runs, extended run period (10 hours maximum), etc.

1 run day required; could split into 2 shifts depending on RF availability.

5.2 Shot sequence plan

For each run day, give detailed specification for proposed shot sequence: number of shots at
each condition, specific parameters and auxiliary systems requirements, etc. Include contin-
gency plans, if appropriate.

Part A:

1) Start with 5.4 T, 800 kA, nel= 9 × 10^{20} m^{-2}. 2 MW RF, at 80 MHz. During H-
Mode, step power down to 1.5 MW or 1 MW to see if the change in T_e affects the H-mode
character. Progressively lower target ne until EDA is lost (4 shots)

2) Reduce Ip to 700 kA, and repeat. (4 shots)

3) Reduce Ip to 600 kA and repeat (4 shots)

4) IF 600 kA EDA’s look OK, and it seems pedestal density is indeed dropping with
Ip, repeat at 500 kA. (4 shots)

Part B:

Return to most promising, steady, low density H-mode. Increase total RF input power,
shot to shot, to maximize core T_e. Use maximum available ICRH; ideally 4 MW but 3
would be a start. Prefer all 80 MHz, but could use some at 70 MHz. Also, document
whether EDA/ELM character changes as T_e is raised; it is possible that QC mode will
require higher ne at higher T (lower collisionality). If so, we need to find out now.

(6 shots)

If time permits, repeat at more than one current/density combination.

6. Anticipated Results

Discuss possible experimental outcomes and implications. Indicate if the program may be expected
to lead to publications, milestone completions, improved operating techniques, etc. Indicate if
the experiments are intended to contribute to a joint research effort, or an external database.

This experiment is part of the ‘Scenario Development/Density Control’ part of the AT
program, and was included in the high priority experiments for this year. It will provide
important data for AT modelling and experimental planning. It is important to get these
results before the end of the ‘pre-LH’ campaign, and before upcoming program reviews
etc.

7. References

Include references both to external and internal literature or communications which bear on this
proposal. See Section 2.